CONTENTS

Chapter		Page
	ACKNOWLEDGMENTS I ACKNOWLEDGMENTS II ABSTRACT CONTENTS FIGURES TABLES	ii iii iv v xv xv
1	INTRODUCTION AND PROCESS CAPABILITIES	
	1.1 Purpose 1.2 Scope 1.3 Treatment Processes 1.4 Slow Rate Process 1.4.1 Process Objectives 1.4.2 Treatment Performance 1.5 Rapid Infiltration 1.5.1 Process Objectives 1.5.2 Treatment Performance 1.6 Overland Flow 1.6.1 Process Objectives 1.6.2 Treatment Performance 1.7 Combination Systems 1.8 Guide to Intended Use of the Manual 1.9 References	1-1 1-2 1-4 1-4 1-8 1-8 1-9 1-11 1-13 1-14 1-13
2	PLANNING AND TECHNICAL ASSESSMENT	
	2.1 Planning Procedure 2.2 Phase 1 Planning 2.2.1 Preliminary Data 2.2.2 Land Treatment System Suitability 2.2.3 Land Area Requirements 2.2.4 Site Identification 2.2.5 Site Screening	2-1 2-1 2-1 2-9 2-16 2-16 2-22
	2.3 Phase 2 Planning 2.3.1 Field Investigations 2.3.2 Selection of Preliminary Design Criteria 2.3.3 Evaluation of Alternatives 2.3.4 Plan Selection	2-27 2-27 2-27 2-29 2-34
	2.4 Water Rights and Potential Water Rights Conflicts 2.4.1 Natural Watercourses 2.4.2 Surface Waters 2.4.3 Percolating Waters (Ground Waters) 2.4.4 Sources of Information	2-34 2-35 2-37 2-37 2-38
	2.5 References	2-38

Chapter			Page
3		D INVESTIGATIONS	3-1
		Introduction	3-1
	3.2	Physical Properties	3-1
		3.2.1 Shallow Profile Evaluation	3-3
		3.2.2 Profile Evaluation to	
		Greater Depths	3-4
	3.3	<u> </u>	3-4
		3.3.1 Saturated Hydraulic Conductivity	3-5
		3.3.2 Infiltration Capacity	3-6
		3.3.3 Specific Yield	3-8
		3.3.4 Unsaturated Hydraulic Conductivity	
		3.3.5 Profile Drainage	3-10
	3.4		3-10
		3.4.1 Flooding Basin Techniques	3-13
		3.4.2 Cylinder Infiltrometers	3-17
		3.4.3 Sprinkler Infiltrometers	3-20
	3.5	Measurement of Vertical Hydraulic	
		Conductivity	3-22
		3.5.1 Double-Tube Method	3-24
		3.5.2 Air Entry Permeameter	3-24
	3.6	Ground Water	3-27
		3.6.1 Depth/Hydrostatic Head	3-28
		3.6.2 Flow	3-30
		3.6.3 Ground Water Quality	3-36
	3.7		3-36
		3.7.1 Interpretation of Soil	
		Chemical Tests	3-37
		3.7.2 Phosphorus Adsorption Test	3-38
	3.8		3-39
4	SLOW	RATE PROCESS DESIGN	
	4.1	Introduction	4-1
	4.2	Process Performance	$\frac{1}{4} - 1$
	1.2	4.2.1 BOD and Suspended Solids Removal	$\frac{1}{4} - 1$
		4.2.2 Nitrogen	4-3
		4.2.3 Phosphorus	4-5
		4.2.4 Trace Elements	4-7
		4.2.5 Microorganisms	4-7
		4.2.6 Trace Organics	4-10
	4.3		$\frac{4-10}{4-11}$
	4.3	4.3.1 Guidelines for Crop Selection	4-11
	1 1	4.3.2 Crop Characteristics	4-15
	4.4		4-24
		4.4.1 Preapplication Treatment for	4 05
		Storage and During Storage	4-25
		4.4.2 Preapplication Treatment to	4 0-
		Protect Distribution Systems	4-27

Chapter				Page
	4.5	Loading	Industrial Pretreatment g Rates and Land Area Requirements	4-28 4-28
		4.5.1	on Soil Permeability	4-28
		4.5.2	Hydraulic Loading Rate Based	4-30
		4.5.3	on Nitrogen Limits Hydraulic Loading Rate Based	4-30
			on Irrigation Requirements	4-34
	4 6	4.5.4	-	4-35
	4.6	_	e Requirements	4-37
		4.0.1	Estimation of Volume Requirements Using Storage Water Balance	
			Calculations	4-37
		4.6.2		4 37
		1.0.2	Requirements Using Computer	
			Programs	4-39
		4.6.3	_	
			Calculations	4-41
		4.6.4	5	4-43
	4.7		oution System	4-44
			Surface Distribution Systems	4-44
			Sprinkler Distribution Systems	4-45
		4.7.3		4 52
	4 0	Daoine	System Components	4-53 4-53
	4.8	-	ge and Runoff Control Subsurface Drainage Systems	4-53
		4.8.2		4-56
	4.9		Management	4-58
	1.,,	-	Soil Management	4-58
			Crop Management	4-61
	4.10		Monitoring	4-64
		4.10.1	Water Quality Monitoring	4-65
			Soils Monitoring	4-65
			Vegetation Monitoring	4-66
		_	ties Design Guidance	4-66
	4.12	Refere	nces	4-68
5	ודתולם	י דאודידי	TRATION PROCESS DESIGN	
5	5.1	Introdi		5-1
	J.1	5.1.1		5-1
		5.1.2	Site Work	5-1
	5.2	Process	s Performance	5-3
		5.2.1		5-3
		5.2.2	Nitrogen	5-3
			Phosphorus	5-5
			Trace Elements	5-6
			Microorganisms	5-8
		5.2.6	Trace Organics	5-9

Chapter			Page
	5.3	Determination of Preapplication	
		Treatment Level	5-10
		5.3.1 EPA Guidance	5-10
		5.3.2 Water Quality Requirements	
		and Treatment Goals	5-10
	5.4	Determination of Hydraulic	
		Loading Rate	5-12
		5.4.1 Measured Hydraulic Capacity	5-12
		5.4.2 Selection of Hydraulic Loading	
		Cycle and Application Rate	5-14
		5.4.3 Other Considerations	5-17
	5.5	Land Requirements	5-22
		5.5.1 Infiltration Basin Area	5-22
		5.5.2 Preapplication Treatment	
		Facilities	5-22
		5.5.3 Other Land Requirements	5-22
	5.6	<u>-</u>	5-23
		5.6.1 Distribution and Basin Layout	5-23
		5.6.2 Storage and Flow Equalization	5-27
		5.6.3 Cold Weather Modifications	5-27
	5.7	Drainage	5-28
		5.7.1 Subsurface Drainage to	
		Surface Waters	5-28
		5.7.2 Ground Water Mounding	5-30
		5.7.3 Underdrains	5-38
		5.7.4 Wells	5-42
	5.8		5-42
		5.8.1 Monitoring	5-42
		5.8.2 Maintenance	5-44
	5.9	Design and Construction Guidance	5-45
		References	5-46
6	OVER	LAND FLOW PROCESS DESIGN	
	6.1	Introduction	6-1
		6.1.1 Site Characteristics and	
		Evaluation	6-1
		6.1.2 Water Quality Requirements	6-1
		6.1.3 Design and Operating Parameters	6-3
	6.2	Process Performance	6-3
		6.2.1 BOD Removal	6-3
		6.2.2 Suspended Solids Removal	6-6
		6.2.3 Nitrogen Removal	6-6
		6.2.4 Phosphorus Removal	6-8
		6.2.5 Trace Element Removal	6-8
		6.2.6 Mircroorganism Removal	6-8
		6.2.7 Trace Organics Removal	6-9
		6.2.8 Effect of Rainfall	6-9

Chapter		Page
	6.2.9 Effect of Slope Grade 6.2.10 Performance During Startup 6.3 Preapplication Treatment 6.4 Design Criteria Selection 6.4.1 Hydraulic Loading Rate 6.4.2 Application Rate 6.4.3 Application Period 6.4.4 Application Frequency 6.4.5 Constituent Loading Rates 6.4.6 Slope Length 6.4.7 Slope Grade	6-10 6-10 6-11 6-12 6-12 6-13 6-14 6-14 6-14
	6.4.8 Land Requirements 6.5 Storage Requirements 6.5.1 Storage Requirements for	6-15 6-18
	Cold Weather 6.5.2 Storage for Stormwater Runoff 6.5.3 Storage for Equalization	6-18 6-19 6-21
	6.6 Distribution 6.6.1 Surface Methods 6.6.2 Low Pressure Sprays 6.6.3 High Pressure Sprinklers 6.6.4 Buried Versus Aboveground Systems 6.6.5 Automation	6-22 6-22 6-24 6-25 6-27
	6.7 Vegetative Cover 6.7.1 Vegetative Cover Function 6.7.2 Vegetative Cover Selection	6-27 6-27 6-28
	6.8 Slope Construction 6.8.1 System Layout 6.8.2 Grading Operations 6.8.3 Seeding and Crop Establishment	6-28 6-28 6-29 6-29
	6.9 Runoff Collection 6.10 System Monitoring and Management 6.10.1 Monitoring 6.10.2 System Management	6-31 6-32 6-32 6-32
	<pre>6.11 Alternative Design Methods 6.11.1 CRREL Method 6.11.2 University of California,</pre>	6-34 6-34
	Davis, (UCD) Method 6.11.3 Comparison of Alternative Methods 6.12 References	6-36 6-38 6-39
7	SMALL SYSTEMS 7.1 Introduction 7.2 Facility Planning 7.2.1 Process Considerations 7.2.2 Site Selection 7.2.3 Site Investigations	7-1 7-1 7-1 7-5 7-8

Chapter			Page
	7.3	Facility Design 7.3.1 Preapplication Treatment	7-9
	7.4	and Storage 7.3.2 Hydraulic Loading Rates 7.3.3 Land Area Requirements 7.3.4 Distribution Systems	7-9 7-10 7-15 7-16 7-17 7-17 7-22
	7.5	7.4.4 Overland Flow	7-30 7-31
8	8.1 8.2	8.4.1 Areas of Potential Energy Savings 8.4.2 Example: Energy Savings in Slow Rate Design 8.4.3 Summary Procedures for Energy Evaluations 8.5.1 Slow Rate 8.5.2 Rapid Infiltration 8.5.3 Overland Flow 8.5.4 Examples	8-1 8-2 8-4 8-4 8-5 8-6 8-6 8-10 8-11 8-12 8-13 8-13 8-13 8-16 8-17 8-18
9	HEAL 9.1 9.2	Introduction Nitrogen 9.2.1 Crops 9.2.2 Ground Water 9.2.3 Surface Water Phosphorus 9.3.1 Soils 9.3.2 Crops 9.3.3 Ground Water 9.3.4 Surface Water	9-1 9-3 9-4 9-4 9-5 9-5 9-5

Chapter				Page
	9.4	Dissolve 9.4.1 S 9.4.2 C	oils	9-5 9-5 9-6
	9.5	9.4.3 G Trace El 9.5.1 S 9.5.2 C	round Water ements oils rops	9-6 9-8 9-8 9-9
	9.6	Microorg 9.6.1 S 9.6.2 C	oils	9-11 9-12 9-13 9-14 9-16
	9.7	9.6.5 A Trace Or 9.7.1 S 9.7.2 C	ganics oils rops	9-16 9-17 9-21 9-21 9-22
			round Water urface Water	9-22 9-23
	9.8	Referenc	es	9-24
Appendix				
А			SIGN EXAMPLE	
		Introduc		A-1
	A.2	Statemen	t of Problem	A-1
		A.2.1 B	ackground	A-1
		A.2.2 P	opulation and Wastewater	
			haracteristics	A-1
		A.2.3 D	ischarge Requirements	A-1
			ite Characteristics	A-2
		A.2.5 C	limate	A-2
	A.3	Slow Rat	e System Selection	A-4
			reapplication Treatment	A-4
		A.3.2 C	rop Selection	A-5
	A.4	System D	esign	A-5
			orage Crop Alternative	A-5
			eciduous Forest Crop Alternative	A-22
			elected SR Design	A-28
		A.4.4 E	nergy Requirements	A-28
В			ATION DESIGN EXAMPLE	_
		Introduc		B-1
	B.2		considerations	B-1
			esign Community	B-1
		B.2.2 W	astewater Quality and Quantity	B-1
			xisting Wastewater	5 0
		T	reatment Facilities	B-2

Appendix			Page
		B.2.4 Climate	B-2
		Site and Process Selection	B-3
	В.4	Site Investigations	В-б
		B.4.1 Soil Characteristics	В-б
		B.4.2 Ground Water Characteristics	B-8
		B.4.3 Hydraulic Capacity	B-8
	B.5	5	B-10
		B.5.1 Preapplication Treatment Level	B-10
		B.5.2 Hydraulic Loading Rate	B-10
		B.5.3 Hydraulic Loading Cycle	B-11
		B.5.4 Effect of Precipitation on	
		Wastewater Loading Rate	B-11
		B.5.5 Underdrainage	B-11
	_	B.5.6 Nitrification	B-13
	В.6		B-13
		B.6.1 Preapplication Treatment	_ 10
		Facilities	B-13
		B.6.2 Infiltration Basins	B-14
	B.7	System Design	B-14
		B.7.1 General Requirements	B-14
	ъ О	B.7.2 Underdrainage	B-18
	В.8	<u> </u>	B-18
		B.8.1 Maintenance	B-18
	D O	B.8.2 Monitoring	B-20 B-20
		System Costs Energy Budget	B-20 B-20
		Energy Budget References	B-20 B-22
	Б.11	References	D-77
С		LAND FLOW DESIGN EXAMPLE	
	C.1		C-1
		Statement of the Problem	C-1
	C.3	_	C-1
		C.3.1 Wastewater Characteristics	
		and Discharge Requirements	C-1
		C.3.2 Climate	C-2
	C.4	Site Evaluation and Process Selection	C-2
		C.4.1 General Site Characteristics	C-2
		C.4.2 Soil Characteristics	C-4
		C.4.3 Process Selection	C-4
	C.5	Distribution Method	C-4
		Preapplication Treatment	C-4
	C.7	3	C-5
		C.7.1 Storage Requirement	C-5
	a 0	C.7.2 Storage Facility Description	C-5
	C.8	Selection of Design Parameters	C-6
		C.8.1 Hydraulic Loading Rate	C-6
		C.8.2 Application Period and Frequency	C-6

Appendix		Page
	C.8.3 Slope Length and Grade C.8.4 Application Rate C.8.5 Land Requirements C.9 Distribution System C.10 Preliminary System Layout C.11 System Design C.11.1 Treatment Slopes C.11.2 Runoff Channel Design C.11.3 Collection Waterways C.11.4 Pumping System C-12	C-6 C-7 C-7 C-7 C-9 C-9 C-9 C-9
	C.11.5 Monitoring and Collection System C.12 Land Requirements C.13 Cover Crop Selection C.14 System Costs C.15 Energy Budget	C-13 C-13 C-14 C-14 C-15
	<pre>C.16 Alternative Design Methods - Design Example C.16.1 CRREL Method C.16.2 University of California,</pre>	C-15 C-15
	Davis, Method C.16.3 Comparison of Methods C.17 References	C-17 C-19 C-19
D	LOCATION OF LAND TREATMENT SYSTEMS D.1 Slow Rate Systems D.2 Rapid Infiltration Systems D.3 Overland Flow Systems	D-1 D-5 D-7
E	DISTRIBUTION SYSTEM DESIGN FOR SLOW RATE E.1 Introduction E.2 General Design Considerations E.2.1 Depth of Water Applied E.2.2 Application Frequency E.2.3 Application Rate E.2.4 Application Period E.2.5 Application Zone E.2.6 System Capacity E.3 Surface Distribution System E.3.1 Ridge and Furrow Distribution E.3.2 Graded Border Distribution E.4 Sprinkler Distribution Systems E.4.1 Application Rates E.4.2 Solid Set Sprinkler Systems E.4.3 Move-Stop Sprinkler Systems E.4.4 Continuous Move Systems	E-1 E-1 E-1 E-2 E-2 E-2 E-3 E-4 E-4 E-15 E-15 E-20
	E.5 References	E-31

CONTENTS (Concluded)

Appendix		Page
F	ESTIMATED STORAGE DAYS FOR LAND TREATMENT USING EPA COMPUTER PROGRAMS F-1	
G	GLOSSARY OF TERMS CONVERSION FACTORS	G-1 G-3

FIGURES

No.		Page
1-1	Slow Rate Hydraulic Pathways	1-5
1-2	Rapid Infiltration Hydraulic Pathways	1-10
1-3	Overland Flow	1-12
1 - 4	Examples of Combined Systems	1-15
2-1	Two-Phase Planning Process	2-2
2-2	Potential Evapotranspiration Versus Mean	
	Annual Precipitation	2-11
2-3	Estimated Design Percolation Rate as a	
	Function of Soil Permeability for SR and	
	RI Land Treatment	2-12
2-4	Winter Operation of Rapid Infiltration	
	at Lake George, New York	2-14
2-5	Estimated Wastewater Storage Days Based	
	only on Climatic Factors	2-15
2-6	Total Land Required (Includes Land for	
	Application, Roads, Storage, and Buildings)	2-17
2-7	Example Area of Soil Map to be Evaluated	2-25
2-8	Example Suitability Map for Soils	
	in Figure 2-7	2-26
2-9	Staffing Requirements for Land Treatment	
	Components (not Including Sewer System or	
	Preapplication Treatment) for Municipally	
	Owned and Operated Systems	2-33
2-10	Dominant Water Rights Doctrines and Areas	
	of Water Surplus or Deficiency	2-36
3-1	Flow Chart of Field Investigations	3-2
3-2	Infiltration Rate as a Function of	
	Time for Several Soils	3-7
3-3	Porosity, Specific Retention, and Specific	
	Yield Variations with Grain Size,	
	South Coastal Basin, California	3-9
3-4	General Relationship Between Specific Yield	
	and Hydraulic Conductivity	3-9
3-5	Typical Pattern of the Changing Moisture	
	Profile During Drying and Drainage	3-11
	Flooding Basin Used for Measuring Infiltration	3-13
3-7		3-14
3-8	Schematic of Finished Installation	3-14
3-9	Infiltration Rate and Cumulative Intake Data Plot	3-16
	Cylinder Infiltrometer in Use	3-18
	Layout of Sprinkler Infiltrometer	3-21
	Schematic of Double-Tube Apparatus	3-25
	Schematic of Air-Entry Permeameter	3-25
	Well and Piezometer Installation	3-29
	Vertical Flows Indicated by Piezometers	3-30
3-16	Definition Sketch for Auger-Hole Technique	3-33

FIGURES (Continued)

No.		Page
	Experimental Setup for Auger-Hole Technique	3-33
4-1	Slow Rate Design Procedure	4-2
4-2	Nitrogen Uptake Versus Growing Days for Annual and Perennial Crops	4-17
4-3	Determination of Storage by EPA Computer	
	Programs According to Climatic Constraints	4-40
4 - 4	Surface Distribution Methods	4-46
4-5	Fan Nozzle Used for Spray Application at	
	West Dover, Vermont	4-51
4-6	Solid Set Sprinklers with Surface Pipe	4 50
- 1	in a Forest System	4-52
5-1	Rapid Infiltration Design Procedure	5-2
5-2	Effect of Infiltration Rate on Nitrogen Removal	5-19
5-3	Infiltration Basin Outlet and Splash Pad	5-24
5-4	Interbasin Transfer Structure with	F 0.4
5-5	Adjustable Weir	5-24
5-5	Natural Drainage of Renovated Water Into Surface Water	5-29
5-6	Example Design for Subsurface Flow to Surface Water	5-29
5-7	Schematic of Ground Water Mound	5-32
5-8	Mounding Curve for Center of a Square	5-32
5 0	Recharge Area	5-34
5-9	Mounding Curve for Center of a Rectangular	5 5 1
J ,	Recharge Area at Different Ratios of	
	Length (L) to Width (W)	5-34
5-10	Rise and Horizontal Spread of Mound Below a	0 0 1
	Square Recharge Area	5-36
5-11	Rise and Horizontal Spread of Mound Below a	
	Rectangular Recharge Area Whose Length	
	is Twice its Width	5-37
	Centrally Located Underdrain	5-39
5-13	Underdrain System Using Alternating	
	Infiltration and Drying Strips	5-40
	Parameters Used in Drain Design	5-41
	Well Configurations	5-43
	Overland Flow Design Procedure	6-2
6-2	Surface Distribution Using Gated Pipe for OF	6-23
6-3	Distribution for OF Using Low Pressure	c 24
6 1	Fan Spray Nozzles	6-24
6-4	Alternative Sprinkler Configurations for Overland Flow Distribution	6-26
6-5	Land Plane Used for Final Grading	6-30
7-1	Land Area Estimates for Preliminary Planning	0-30
/ — <u>T</u>	Process (Including Land for Preapplication	
	Treatment)	7-7
7-2	Typical Annual Hydraulic Loading Rate of	, ,
	Small SR and OF Systems	7-12

FIGURES (Concluded)

No.	Page
7-3 Typical Annual Hydraulic Loading Rate of Small SR Systems	7-13
7-4 Overflow Control Structure for Pond Discha	rge
to SR System	7-21
7-5 Treatment Facility Layout - Kennett Square	7-23
Pennsylvania, SR System 7-6 SR Facilities at Kennett Square, Pennsylva	
8-1 Center Pivot System	8-7
8-2 Automatic Surface Irrigation System	8-8
A-1 Soils Map	A-3
A-2 System Layout: Forage Crop Alternative	A-18
A-3 System Layout: Forest Crop Alternative	A-26
B-l Soils Map, Sites 1 and 2	B-4
B-2 Ground Water Contours	B-7
B-3 Intake Curves - Infiltration Basin 1	В-9
B-4 Community B Rapid Infiltration System Flow	rsheet B-15
B-5 Community B Site Layout	B-16
B-6 Underdrain Location	B-19
C-l Proposed Overland Flow Treatment Site	C-3
C-2 Typical Overland Flow Slope	C-8
C-3 Contour Map of Proposed Overland Flow	
Treatment System	C-10
C-4 Overland Flow System Layout	C-11
E-l Surface Distribution Methods	E-5
E-2 Aluminum Hydrant and Gated Pipe at	E-8
Sweetwater, Texas E-3 Outlet Valve for Border Strip Application	E-13
E-3 Outlet Valve for Border Strip Application E-4 Solid Set Sprinkler System	E-15
E-5 Move-Stop Sprinkler Systems	E-22
E-6 Side Wheel Roll Sprinkler System	E-23
E-7 Continuous Move Sprinkler Systems	E-25
E-8 Hose-Drag Traveling Gun Sprinkler	E-26
E-9 Center Pivot Rig	E-30
E-10 Center Pivot Irrigation System	E-30

TABLES

No.		Page
1-1	Comparison of Typical Design Features for	1 2
1 0	Land Treatment Processes	1-3
1-2	Comparison of Site Characteristics for Land Treatment Processes	1-3
1-3	Expected Quality of Treated Water from	1 3
	Land Treatment Processes	1-4
2-1	Important Constituents in Typical	
	Domestic Wastewater	2-3
2-2	Comparison of Trace Elements in Water	
	and Wastewaters	2-4
2-3	Typical BOD Loading Rates	2-4
2-4	National Interim Primary Drinking	0 6
2 [Water Standards, 1977	2-6 2-8
2-5 2-6	Summary of Climatic Analyses Land Use Suitability Factors for	2-0
2-0	Identifying Land Treatment Sites	2-19
2-7	Grade Suitability Factors for	2 1)
۷ ,	Identifying Land Treatment Sites	2-19
2-8	Soil Textural Classes and General	
	Terminology Used in Soil Descriptions	2-21
2-9	Typical Soil Permeabilities and Textural	
	Classes for Land Treatment Processes	2-22
	Site Selection Guidelines	2-23
	Rating Factors for Site Selection	2-24
2-12	Characteristics of Soil Series	0.05
0 10	Mapped in Figure 2-7	2-25
	Example Use of Rating Factors for Site Selection	2-26
Z-1 4	Applicability of Recovery Systems for Renovated Water	2-29
2-15	Lease/Easement Requirements for Construction	22)
2 13	Grants Program Funding	2-31
2-16	Potential Water Rights Problems for	
	Land Treatment Alternatives	2-37
3-1	Summary of Field Tests for Land	
	Treatment Processes	3-3
	Comparison of Infiltration Measurement Techniques	3-12
3-3	Sample Comparison of Infiltration	
	Measurement Using Flooding and	
2 4	Sprinkling Techniques	3-12
3-4	Suggested Vertical Placement of	2 1 5
2 E	Tensiometers in Basin Infiltrometer Tests	3-15
3-5	Measured Ratios of Horizontal to Vertical Conductivity	3-32
3-6	Interpretation of Soil Chemical Tests	3-32
$\frac{3}{4-1}$	BOD Removal Data for Selected SR Systems	4-3
4-2	Nitrogen Removal Data for Selected SR Systems	$\frac{1}{4} - 4$
	<u> </u>	

TABLES (Continued)

No.		Page
4-3 4-4	Phosphorus Removal Data for Typical SR Systems Trace Element Behavior During SR Land Treatment	4-6 4-8
4-5	Suggested Maximum Applications of Trace Elements to Soils Without	
	Further Investigations	4-9
4-6	Coliform Data for Several SR Systems	4-10
4 - 7	Benzene, Chloroform, and Trichioroethylene	
	in Muskegon Wastewater Treatment System	4-11
4-8	Relative Comparison of Crop Characteristics	4-13
4-9	Summary of Operational Forest Land Treatment	
	Systems in the United States Receiving	4-15
4_10	Municipal Wastewater Height Growth Response of Selected Tree Species	4-15
	Nutrient Uptake Rates for Selected Crops	4-15
	Estimated Net Annual Nitrogen Uptake in the	4 10
1 12	Overstory and Understory Vegetation of Fully	
	Stocked and Vigorously Growing Forest	
	Ecosystems in Selected Regions of the	
	United States	4-19
4-13	Biomass and Nitrogen Distribution by Tree	
	Component for Stands in Temperate Regions	4-20
4-14	Examples of Estimated Monthly Potential	
	Evapotranspiration for Humid and	4 01
4 1 5	Subhumid Climates	4-21
4-15	Consumptive Water Use and Irrigation Requirements	
	for Selected Crops at San Joaquin Valley, California	4-22
4-16	Summary of Wastewater Constituents Having	4-22
1 10	Potential Adverse Effects	4-24
4-17	Water Balance to Determine Hydraulic Loading	
	Rates Based on Soil Permeability	4-31
4-18	Estimating of Storage Volume Requirements	
	Using Water Balance Calculations	4-38
4-19	Summary of Computer Programs for Determining	
	Storage from Climatic Variables	4-39
	Final Storage Volume Requirement Calculations	4-42
4-21	Surface Distribution Methods and	4 4 7
4 00	Conditions of Use	4-47
4-22	Advantages and Disadvantages of Sprinkler	
	Distribution Systems Relative to	4-49
1-23	Surface Distribution Systems Sprinkler System Characteristics	4-49
	Suggested Service Life for Components of	4-43
1 41	Distribution System	4-54
4-25	Recommended Design Factors for	1 31
	Tailwater Return Systems	4-57

TABLES (Continued)

No.		Page
4-26	Approximate Critical Levels of Nutrients	4 50
4 07	in Soils for Selected Crops in California	4-59
4-27	Grazing Rotation Cycles for Different	4 60
4 00	Numbers of Pasture Areas	4-62
	Recommended Soil Contact Pressure	4-67
5-1	<u> -</u>	5-4
5-2	Nitrogen Removal Data for Selected RI Systems	5-5
5-3	Phosphorus Removal Data for Selected RI Systems	5-6
5-4	Comparison of Trace Element Levels to	F 7
	Irrigation and Drinking Water Limits	5-7
5-5	Heavy Metal Retention in an Infiltration Basin	5-7
5-6	Fecal Coliform Removal Data for Selected	г о
	RI Systems	5-8
5-7	Reported Isolations of Virus at RI Sites	5-9
5-8	Recorded Trace Organic Concentrations at	Г 10
г о	Selected RI Sites	5-10
5-9		5-11
	Typical Hydraulic Loading Rates for RI Systems	5-13
	Suggested Annual Hydraulic Loading Rates	5-14 5-16
	Typical Hydraulic Loading Cycles	5-16
	Suggested Loading Cycles	5-17
2-14	Minimum Number of Basins Required for	5-25
6-1	Continuous Wastewater Application OF Design and Operating Parameters	5-25 6-3
6-2	Summary of Process Operating Parameters,	0-3
0-2	BOD and SS Performance at OF Systems	6-4
6-3	Summary of Nitrogen and Phosphorus	0-4
0-3	Performance at OF Systems	6-5
6-4	Removal Efficiencies of Heavy Metals at	0 3
0 4	Different Hydraulic Rates at Utica, Mississippi	6-9
6-5	Overland Flow Design Guidelines	6-12
7-1	Types and Sources of Data Required for Design	0 12
, _	of Small Land Treatment Systems	7-2
7-2		7 2
7	Land Treatment Systems	7-3
7-3	Typical Staffing Requirements at Small Systems	7-6
7-4	Recommended Level of Preapplication Treatment	7-9
7-5	Typical Design Parameters for Several	, ,
, ,	Types of Ponds	7-10
7-6	Nitrogen Uptake Rates for Selected Crops	7-14
7-7	Design Information for SR System	7-19
7-8	Design Information for Chapman RI System	7-27
7-9	Wastewater Flows to Chapman RI System	7-29
7-10		7-31
8-1	Energy Requirements for Crop Production	8-4
8-2	Most Common Unit Energy Requirements for	~ -
. –	Land Treatment of Municipal Wastewater	8-5

TABLES (Continued)

No.		Page
8-3 8-4	Example System Characteristics Comparison of Conventional and Automated Ridge	8-8
8-5	and Furrow Systems for 38,000 m ³ /d Comparison of Impact and Drop-Type Center Pivot System Nozzle Designs on Energy Requirements	8-9 8-10
8-6	Total Annual Energy for Typical 3,785 m ³ /d System	8-10
9-1	Land Treatment Methods and Concerns	9-2
9-2	Relationship of Pollutants to Health Effects	9-2
9-3	EPA Long-Term Effects Studies	9-3
9-4	Tolerance of Selected Crops to Salinity in Irrigation Water	9-7
9-5	Mass Balance of Trace Elements in OF System	
	at Utica, Mississippi	9-9
9-6	Trace Element Content of Forage Grasses at Selected SR Systems	9-11
9-7	Trace Element Drinking and Irrigation	
	Water Standards	9-12
9-8	Virus Transmission Through Soil at RI Systems	9-15
9-9	Aerosol Bacteria at Land Treatment Sites	9-18
9-10	Aerosol Enteroviruses at Land Treatment Sites	9-19
9-11	Comparison of Coliform Levels in Aerosols at Activated Sludge and Slow Rate Land	
	Treatment Facilities	9-20
	Trace Organics Removals During Sand Filtration	9-21
	Trace Organics Removals at Selected SR Sites	9-23
9-14	Removal of Refractory Volatile Organics by	
	Class at Phoenix RI Site	9-23
	Chloroform and Toluene Removal During OF	9-24
A-1	-	A-2
A-2	Climatic Data for the Worst Year in 5	A-4
A-3	Hydraulic Loading Rates Based on Soil	_
_	Permeability: Forage Crop Alternative	A-7
A-4	Design Hydraulic Loading Rate	A-9
A-5	Storage Volume Determination: Forage	
	Crop Alternative	A-11
	Final Determination of Storage Volume	A-14
A-7	Design Criteria for Storage Lagoons:	- 4-
_	Forage Crop Alternative	A-15
A-8	Slow Rate System Design Data: Forage	
	Crop Alternative	A-19
A-9	Cost Estimate Criteria: Forage Crop Alternative	A-19
A-10	Cost Estimate Calculations:	_
	Forage Crop Alternative	A-20
	Summary of Costs: Forage Crop Alternative	A-21
A-12	Initial Determination of Storage Volume:	
	Forage Crop Alternative	A-23

TABLES (Concluded)

No.		Page
A-13	Design Data for Storage Pond: Forest	- 04
- 11	Crop Alternative	A-24
	Design Data: Forest Crop Alternative	A-25
	Summary of Cost: Deciduous Forests	A-27
B-l		B-1
B-2	Surface Water Discharge Requirements	B-2
B-3	Average Meteorological Conditions	B-3
B-4	General Soil Characteristics: Sites 1 and 2	B-5
B-5	Typical Log of Test Hole	B-6
B-6	Ground Water Quality	B-8
B-7	Cost of Community B RI System	B-21
C-1	Raw Wastewater Characteristics	C-1
C-2	Average Meteorological Conditions	C-2
C-3	Storage Requirements	C-5
C-4	Land Requirements	C-13
C-5	Cost of Community C OF System	C-14
E-l	Optimum Furrow Spacing	E-6
E-2	Suggested Maximum Lengths of Cultivated Furrows	
	for Different Soils, Grades, and Depths of	E-6
т. Э	Water to be Applied Paging Chidalines for Chaded Bander Distribution	F-0
E-3	Design Guidelines for Graded Border Distribution, Deep Rooted Crops	E-11
E-4	Design Guidelines for Graded Border Distribution, Shallow Rooted Crops	E-11
E-5	Recommended Reductions in Application Rates	
	Due to Grade	E-15
E-6	Recommended Spacing of Sprinklers	E-18
E-7	Factor (F) by Which Pipe Friction Loss is	
	Multiplied to Obtain Actual Loss in a Line	
	with Multiple Outlets	E-19
E-8	Recommended Maximum Lane Spacing for	
	Traveling Gun Sprinklers	E-28
F-1	Storage Days Using EPA-1 for 20 Year (5%)	
	and 10 Year (10%) Return Intervals	F-1
F-2	Storage Days Using EPA-2 for 20 Year (5%)	
	and 10 Year (10%) Return Intervals	F-2
F-3	Storage Days Using EPA-3 for 20 Year (5%)	
	and 10 Year (10%) Return Intervals	F-3